GALL INSECTS AND THEIR RELATIONS TO PLANTS

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ABUNDANT food, protection from adverse natural agents and minimum exertion are ideals cherished by many. The first two appeal strongly to the infant, the second to the growing child, while the third may become increasingly dominant with the progress of adult years. Solomon advised the sluggard to go to the ant, probably because he had no sympathy with physical or mental inertia; otherwise he might have said: "Consider the gall insect; it does not sow, yet it reaps; it does not build, yet it is sheltered; it gives nothing and receives abundantly."

Easy living is attractive and it is not surprising to learn that representatives of a number of large groups of insects have developed in this direction. In other words, the term "gall insects" does not represent a systematic entity; it is an assemblage of diverse forms grouped because of similar habits. Before proceeding farther, let us agree as to just what is meant by the term "gall." Insect galls may be defined as vegetable excrescences resulting from insect activities and usually sheltering the immature stages of the producers, though a wide acquaintance with these growths demonstrates the existence of innumerable gradations between the apparently normal and the decidedly abnormal, and as a consequence it is difficult to establish a satisfactory distinction between insect galls and deformations not worthy of classification in this category. Some would include the mere curling of leaves and while to a certain extent this is justified, in most cases, unless the curling is pronounced, the deformation has not been considered as an insect gall. Galls caused by insects and their allies are known as Zoöcecidia; those produced by plants are termed Phytocecidia.

The origin and development of these growths are not less interesting than the deformities themselves. The gall-making habit among insects has undoubtedly developed independently in several widely separated groups and must have originated

in a mutual reaction between the insects and their host plants, which has reached its climax in many apparently inexplicable deformities of the present day. All stages of the process may be observed among the gall midges, some of which live among succulent fungus growths and either feed a little upon the fungi or obtain nourishment by absorption from the humid surfaces of the host. There are certain predaceous maggots in this group which have the mouth parts greatly prolonged and apparently especially adapted to withdraw by suction the body fluids of their hosts. It may be one or the other or possibly a combination of the two methods which obtains among the fungus-inhabiting forms. It is only a step from this to absorption with apparently no mechanical injury, as in the leaf spot gall of the soft maple or the pod leaf galls of ash and spiraea. The habit once started, it is possible to understand how the process might continue with indefinite variations among a host of species, which is just what has taken place. The adaptations have continued along a number of lines to such an extent that many gall insects live at the expense of their hosts and in some instances, at least in the case of certain plant lice, the mere satisfying of the primitive pangs of hunger seems to be all that is necessary to compel or cajole, as it were, a host plant to grow or throw around its enemy a defensive barrier or gall within which the aphid may live in the presence of abundance, be comparatively safe and obtain like conditions for its numerous progeny. This sheltered, luxurious type of existence appears to be essential to many species and the tendencies along these lines have developed to such an extent that twenty-nine species of gall-making aphids, Phylloxera, are known to live at the expense of our hickories and in a similar manner a number of species of jumping plant lice, Pachypsylla, subsist on hackberry.

Before going further, let us glance for a moment at the different types of insects possessing this gall-making habit.

The Hymenoptera, best known because of the industrious honeybee, has two important families, the Cynipidæ and the Tenthredinidæ, members of which live in this questionable manner. The first named are minute, four-winged gall flies with legless white maggots. They are moderately numerous in species and remarkable for an alternation of generations; the structural variations between the adults in different generations being so marked, that before the relationship was suspected, they were referred to separate genera. Certain

Cynipids or gall wasps are believed to reproduce only by parthenogenesis. These little insects display a marked partiality for oaks and roses and produce striking types of galls, such as the cortical swellings of the gouty oak gall,[1] a species occasionally becoming so abundant that five hundred thousand individuals may be reared from one tree and its conspicuous galls form giant, bead-like swellings on almost all the smaller branches of a large oak. Occasionally the peculiar bud-like swellings of *Andricus gemmarius* Ashm. are very abundant on pin oaks and the sweet exudation issuing therefrom attracts hosts of bees, flies and similar insects. Another oak gall occasionally numerous is the oak leaf stalk gall.[2] The gall of the wool sower[3] is another striking type and results from the female depositing eggs in a ring of buds around white oak stems, and from the series of wounds inflicted, there develops a seemingly delicate, globose, white, pink-spotted mass which on examination is found to consist of numerous cells, each supported and guarded by a thick fungoid, hairy growth. A more ordinary type may be seen in the familiar banded bullet gall,[4] a representative of a considerable series generally known as "bullet galls."

The gall wasps or Cynipidæ attack plants referable to only six botanical families and but eleven plant genera. There is, however, the most striking limitation in food habits, since a very large proportion of the 445 gall-makers subsist at the expense of the oaks, 38 species have been reared from members of the rose family, 28 of these being species of the genus *Rhodites* and found only upon the rose. The other species of gall wasps are scattered in their food habits, the most evident concentration, and this far from marked, being the 12 species reared from various compositae, the genera *Silphium* and *Lactuca* supporting four and three, respectively.

The gall-making sawflies or Tenthredinidæ produce a great variety of swellings on the willow, mostly upon the leaves. The galls made by these insects exhibit a great proliferation of tissues without distinct layers, according to Dr. Cosens, and are easily recognized by the caterpillar-like inhabitants. The latter are readily distinguished from true caterpillars or Lepidopterous larvæ by the greater number of prolegs. Certain galls, at least, produced by members of this group develop

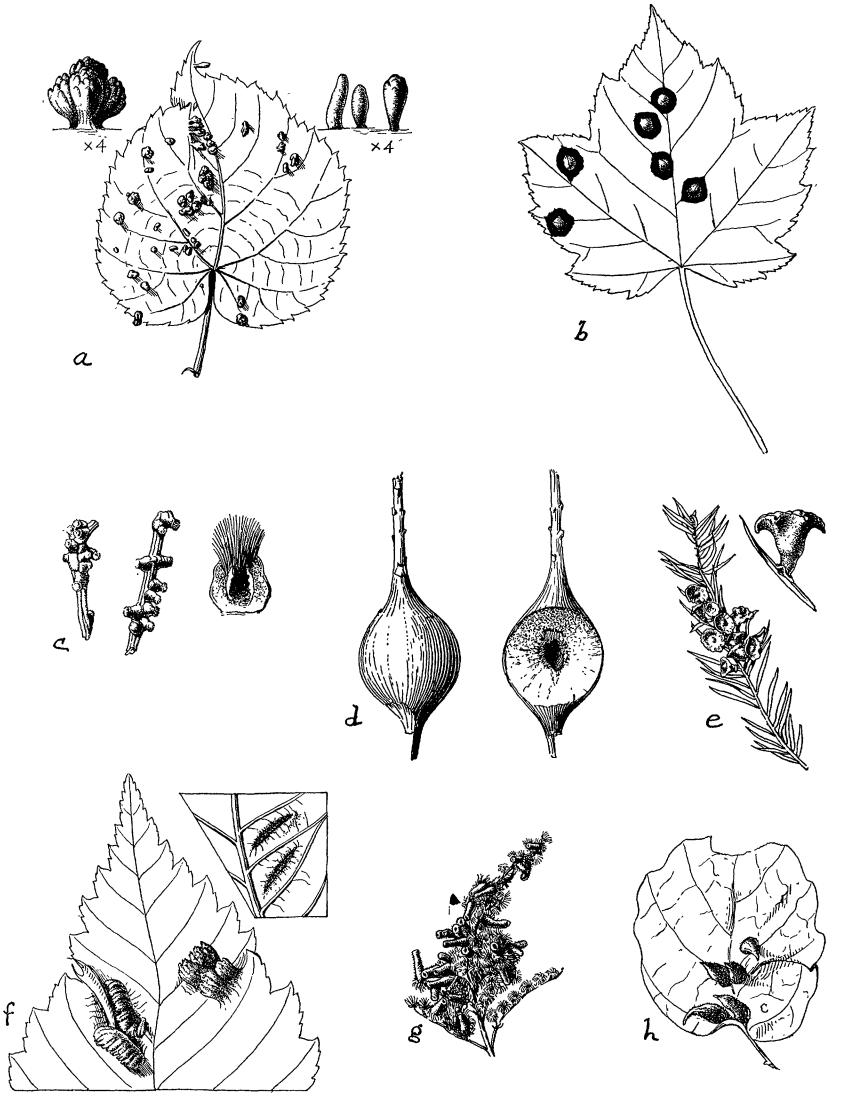
[1] *Andricus punctatus* Bass.
[2] *Andricus petiolicola* Bass.
[3] *Andricus seminator* Harris.
[4] *Disholcaspis fasciata* Bass.

to a considerable extent before the eggs hatch—a hypertrophy resulting probably from chemical stimuli produced by fluids in or deposited with the eggs and transmitted by osmosis.

The beetles or Coleoptera are so respectable that relatively few species of three families, namely, the Buprestidæ or metallic wood borers, the Cerambycidæ or long-horned wood borers and the Curculionidæ or weevils, live in galls. The deformities are largely the result of mechanical obstructions or stimuli and present little of special interest. The representatives of several families of moths or Lepidoptera, the Sesiidæ, the Gelechiidæ and the Tineidæ produce galls of the mechanical type and as in the beetles, the habit is by no means general.

Two families of the Diptera or two-winged flies are noted for their gall producers, namely, the gall midges or Itonididæ and close relatives of the fruit flies or Trypetidæ. The first named is the banner group among gall insects and are ancient and of presumably honorable lineage, since remains of a number of genera and species have been found in the Baltic amber, two species have been discovered in the tertiary Oligocene beds of the White River, while a Pleistocene swamp deposit of Maryland contains swellings upon the leaves of the bald cypress which, in the opinion of Dr. Howard, were produced by a gall midge. This large family of small flies contains some nine hundred known American species, this being probably only a third or a fifth of the fauna. These delicate midges range in length from ¼ to 1/50 of an inch and present marked diversities in habits and structures. There are striking differences in food habits between this large group of gall-making midges and the gall-making wasps referred to above.

In the first place the 679 galls produced by midges occur on plants belonging to 69 botanical families and 202 plant genera. The larvæ of 66 species live at the expense of the Salicaceæ (52 occurring on willow); 29 species subsist upon the Juglandaceæ, all but one infesting hickory; 42 attack members of the oak family (35 of these being upon oaks); 56 produce galls on the Rosaceæ; 24 on the Legumes, 22 upon the grape and close allies and 150 on the composites. The most obvious concentration of species, aside from those mentioned above, is the 44 midges reared from golden rod and the 22 found upon aster. These approximate figures indicate that the group has been able to maintain itself upon a great many different plants through a considerable physiological adaptability and that the distinctness of the species has been established by relatively small modifications in structure.



DIFFERENT TYPES OF GALLS: *A.* Linden mite gall, sometimes very abundant on basswood leaves, note the varied forms. The interior is inhabited by microscopic plant mites. *B.* Maple spot gall, a yellowish-red margined gall, very common on soft maple; at the center there is an almost transparent maggot. *C.* Bud gall on the western rayless goldenrod, note the protecting brush of plant hairs shown in the enlarged section. *D.* Goldenrod ball gall, very common, each inhabited by a large stout yellowish-white maggot. *E.* Cypress flower gall, a peculiar whitish flower-shaped growth sometimes very abundant on the twigs. *F.* Cockscomb elm gall, a deformity produced by a plant louse and occasionally very abundant on small trees, the slit-like entrance on the under surface of the leaf is shown in the upper right-hand figure. *G.* Downy flower gall, sometimes very abundant on goldenrod. *H.* Witch hazel cone gall, a greenish or reddish gall, sometimes very abundant and produced by a plant louse.

A few galls of the Trypetidæ are well known, particularly the common globular stem swelling on golden-rod known as the golden-rod bullet gall.[5] This deformation is simply a stem swelling about an inch long containing near its center a yellowish-white legless maggot.

The Agromyzidæ, another Dipterous family comprising small and usually overlooked flies, has several rather common though generally ignored gall makers. Oval subcortical swellings upon willow and poplar twigs are frequently abundant. Those on the willow may be produced by a sawfly larva, though we have yet to obtain from the poplar twig gall any other maker except *Agromyza schineri* Giraud.

Most galls produced by Diptera are closed and are easily recognized by the legless maggots inhabiting them. The larvæ of the gall midges are peculiar in the possession of a so-called "breast bone" or "anchor" process, though this structure is not evident in all gall midge maggots, especially the very young stages.

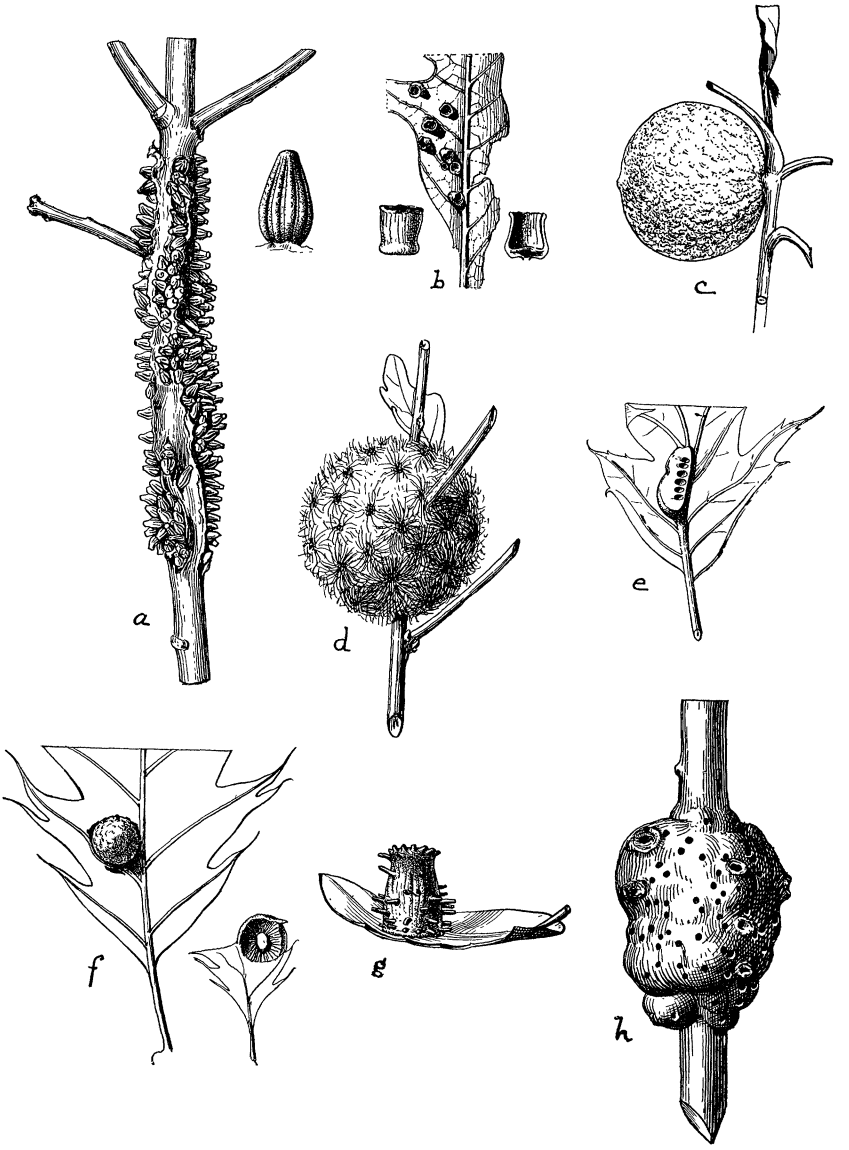
The true bugs or Hemiptera have well-known gall-makers in two families, the plant lice or Aphididæ and the jumping plant lice or Psyllidæ. The former is a large group with occasional species producing galls upon a great variety of plants. Species of jumping plant lice, *Pachypsylla*, inhabit a variety of leaf and stem galls on the hackberry, being strictly limited to this host.

Hemipterous galls are characterized by an opening due to the fact that in some cases, at least, the tissues grow up over and nearly enclose the founder of the gall and eventually form a hollow mass of living tissues with the inner walls nearly covered by plant lice, a condition strongly suggesting the geode of the mineralogist. Certain species of *Phylloxera*, *Pemphigus* and *Chermes* inhabit characteristic and rather common galls. Some of these species produce a considerable series of generations each year and certain of them may inhabit very diverse galls upon entirely different food plants. One of the most interesting of these is the maker of the spiny witch-hazel gall[6] with its summer generations developing upon and corrugating the leaves of birch. The complicated life history of this insect has been carefully worked out by the late Theodore Pergande, a painstaking student of various plant lice.

The plant mites or Eriophyidæ comprise an important division of the *Acarina* and are best known because of the sack-

[5] *Eurosta solidaginis* Loew.

[6] *Hamamelistes spinosus* Shimer.



CHARACTERISTIC OAK GALLS: *A.* Bud-like galls on oak twigs, sometimes very abundant and since they produce a sweetish fluid, hosts of bees, flies and other insects may be attracted in early summer. *B.* Oak spangles, produced by a gall midge, note the cup-like shape and the little oval cavity at the base, shown in the illustration of a sectioned gall. *C.* Large oak apple, one of the more common and striking galls produced by gall wasps. *D.* Gall of the wool sower, a delicate appearing white, pink-marked wooly growth containing seed-like cells, each inhabited by a white maggot. *E.* Mid-rib tumor gall sectioned to show the series of cells inhabited by the white maggots. *F.* Small oak apple, the one in section shows the characteristic central cell inhabited by a maggot and supported by numerous radiating fibers. *G.* A peculiar cylindrical-spined, rosy red, yellow-banded gall on a western oak. *H.* Gouty oak gall, a large swelling frequently forming bead-like enlargements on most of the smaller branches of various oaks, large trees sometimes being badly infested.

like or hairy galls so common on the leaves of certain trees. The microscopic size of the mites renders their study difficult, and this has been a serious hindrance to investigators. There are now listed 161 deformations produced by these minute forms and much remains to be learned concerning American species.

It is evident from the preceding that the gall-making habit has arisen independently among structurally widely separated groups. The underlying causes are the plasticity of vegetable tissues and the adaptability of animals. The insects have simply followed the lines of least resistance. The abundance of individuals and the multiplication of species are closely related to the food supply and insect adaptability. The greater the latter and the wider the range of food habits, the better are the chances for an abundant life so frequently observed in nature. This phase of the subject has interested the speaker for several years and he would review briefly the conditions found among the gall midges.

They comprise an enormous family of small forms, mostly gall-makers. The more generalized present close affinities with the fungous gnats and like them live on fungi or in decaying vegetable matter. *Miastor* and *Oligarces*, two ancient types of gall midges, live in the decaying bark of various trees and in their larvæ we find that form of parthenogenesis known as pedogenesis; that is, maggots produce maggots directly, the egg, pupal and adult stages being eliminated for an indefinite number of generations. Incidentally this biological short cut is an advantage to the species, since it permits multiplication in the remote, narrow crevices of decaying wood, places inaccessible alike to adult midges and to many parasites and predaceous enemies.

By far the largest number of the gall midges are gall-makers, and these are easily distinguished from the lower forms by the greatly reduced first tarsal segment and the presence of circumfili. These latter are also known as "arched filaments" and "bow whorls" because of the remarkable series of loops they form on the male antennal segments in the most specialized tribe. A few of the more generalized tribe, the Epidosariæ, live in dead, occasionally rather dry woody tissues, some being associated with true gall-makers.

The importance of the bud gall in the biology of gall insects is well shown by a tabulation made a few years ago listing 46 as inhabitants of fruit galls, 145 in bud galls, 150 in leaf galls

and 96 in stem galls out of a total of about 437. Fruit galls are potentially bud galls, so that in reality 191 of these were bud galls. *Rhabdophaga* is a genus with a marked preference for willow, and in this we have 12 species inhabiting bud galls, 12 in stem galls and 3 in leaf galls. Though apparently not conclusive, the evidence in this case is really in favor of the bud gall, when we realize that most species of *Rhabdophaga* live on willow; and after making allowance for the softness of the shoot and the rapidity of the growth, it is perhaps surprising that no more primarily bud inhabiting species find themselves left in the race with the plant, as it were, and issue from a deformity which would ordinarily be classed as a stem gall.

The subject is of such interest as to justify further examination. There are two peculiar fusiform galls on narrow-leaved golden-rod, the golden-rod ribbed gall[7] and the golden-rod stemmed gall,[8] both of which may be found among the florets, on the young leaves and the younger portions of the stem, indicating that the parent midges oviposit in the bud and that here, as in the willow, it is not the fault of the insect if the progeny do not issue from bud galls. Another case is that of the nun midge,[9] a species normally breeding in buds and also issuing from deformed flower heads of both golden-rod and aster, and most interesting of all, from small oval cells between two adherent leaves of golden-rod. These latter start while the leaves are in the bud, and as the growth of the plant is hardly affected, it is easy to find in the field these leaves united at the point of injury, with the petioles in all stages of separation; in other words, the upper portion of the stem develops and separates bases of leaves which in the bud are nearly contiguous.

The question of bud infestation does not end here. Some ten species of Cincticornia have been reared from various leaf galls on oaks, the deformities being scattered irregularly over the surface. Some of these galls never develop beyond the blister stage and others form conspicuous, more or less globular, reddish swellings. The primary infestation, we are convinced, occurs while the plastic leaf tissues are in the bud and the same appears to be true of the 18 different leaf galls of *Caryomyia* on *Carya*. These two genera alone give 28 potential bud galls and turn the balance most strongly in favor of the plant bud as the primary source of such deformities. It

[7] *Rhopalomyia fusiformis* Felt.
[8] *Rhopalomyia pedicellata* Felt.
[9] *Asphondylia monacha* O. S.

may be well to add here that the needle-tipped ovipositor of *Asphondylia,* preeminently a bud-inhabiting genus, appears particularly fitted to probe or pierce tender bud tissues.

It happens that over half of the stem galls produced by reared American gall midges result from the activities of the Lasiopterariæ, a highly specialized assemblage producing 52 stem, 12 leaf, 2 bud and but 1 fruit gall. This fact suggests that a high degree of specialization among gall midges is prerequisite to the successful invasion of the harder tissues of the stem.

The fruit gall, botanically speaking, is nothing more than a restriction of attack to flower and fruit, rather than to leaf buds, with such a slow or late development of the insect that the deformity appears in the fruit rather than as a blasting of the blossom. There are a number of seed-inhabiting gall midges. The pear and the fruit of our wild cherry are also subject to attack by members of this group.

Leaf galls include a large number of deformations. The simplest type is a leaf roll, such as the marginal fold gall[10] on oak. Leaf rolls may be rather loose or comparatively tight. Vein folds are common, one of the most abundant being the ash midrib gall,[11] which is simply a large tumid thickening of the midrib on ash leaves. Enlargements of leaf veins may be limited to a rather definite situation, as in the case of the purple vein midge,[12] or they may fuse with irregular enlargements of adjacent tissues and produce a swelling like the grape tomato gall,[13] rather common on leaves and tendrils of grape.

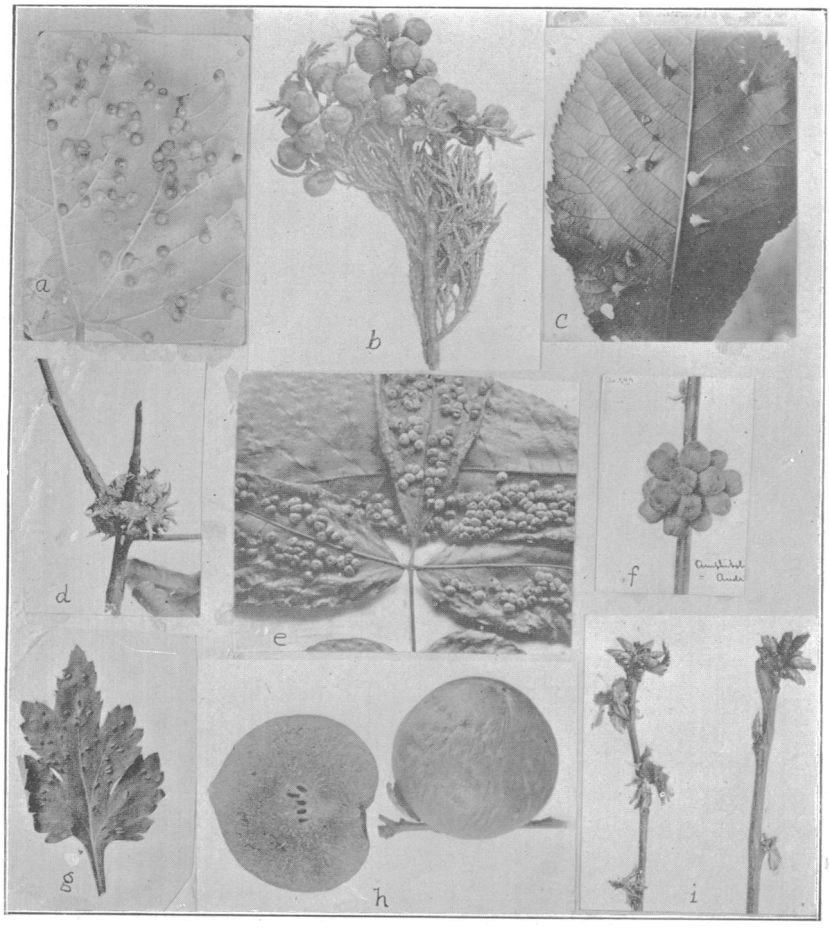
The leaf tissues between the veins may be invaded, one of the simplest types being a small pustule on the oak produced by *Cincticornia simpla* Felt. This may be extended to form a mine as in the purple leaf blotch[14] on *Cratægus* or as a result of the proliferation of tissues develop into a globose, conical or even cylindric swelling.

Stem galls may be classed as medullary and subcortical, the former occurring mostly in herbaceous vegetation and in the smaller limbs or shoots of shrubs and trees. They may be inhabited by one or more larvæ, which usually occur in a more or less definite channel along the pith, as in the case of the aster stem gall.[15] The subcortical type of gall is common in

[10] *Itonida foliora* Rssl. and Hkr.
[11] *Contarinia canadensis* Felt.
[12] *Sackenomyia viburnifolia* Felt.
[13] *Lasioptera vitis* O. S.
[14] *Lasioptera excavata* Felt.
[15] *Neolasioptera ramuscula* Beutm.

herbaceous plants and is the predominant type of stem gall in woody plants. It is generally polythalamous, frequently eccentric and, as stated earlier, is usually produced by a rather highly specialized gall midge.

Only a few species are known to produce root galls, probably because of the greater difficulty in finding them. There seems to be no marked difference between root and stem swellings aside from their location.



DIFFERENT TYPES OF GALLS: *A*. Globular greenish or reddish galls on grape. *B*. Swollen fruit of the western juniper, the interior of which was literally alive with microscopic plant mites. *C*. Hickory seed galls, showing a type with very slender tips. *D*. Horned oak gall, a peculiar growth on oak twigs, with harder horn-like projections within which the whitish gall wasp maggots live. *E*. Typical hickory-leaf midge galls showing extreme abundance. *F*. A peculiar clustered bud gall on oak. *G*. Galls of the chrysanthemum gall midge, a recently introduced and very destructive European species. *H*. Apple-like oak gall, a western giant with a diameter an inch to an inch and a half. *I*. Elm bud galls, many midges and gall wasps live in buds and prevent their development.

Malformations produced by gall-midge larvæ appear to result largely, if not entirely, from mechanical or chemical stimuli produced by the larvæ. The size of the gall is, generally speaking, proportional to the number or size of the larvæ and with the death of the active agent, development of abnormal tissues soon ceases. This is particularly well marked in the beaked willow gall,[16] the aborted ones producing only parasites. There is a close relation between the midge and its gall and, generally speaking, a series of flies reared from the gall are the true producers, though inquilines and predaceous gall midges are by no means unknown. For example, the grape tomato gall may produce five species of midges referable to as many genera and the same is true of the swollen wild cherries inhabited by midge larvæ.

Certain genera of gall midges are predaceous, this being well marked in the genus *Lestodiplosis,* an enemy of other gall midges; *Aphidoletes,* an enemy of aphids; *Mycodiplosis,* some species of which prey upon scale insects, and *Arthrocnodax,* with a marked preference for plant mites.

The larvæ of gall midges are mostly legless, usually yellowish or yellowish orange, sometimes nearly transparent and generally with a well-developed "breast bone" or "anchor" process. This structure and the supernumerary segment just behind the head are characteristic. These maggots also have the power of throwing themselves some distance; the two extremities are approximated and then extended with a snap that projects the larva into the air. Midge larvæ living exposed upon leaves usually develop some protective device such as a series of tubercles, as in the case of the larva of the gouty pine midge,[17] after it leaves the gall. The transparent maker of the maple spot gall[18] is another striking example of protective modifications.

The minute size of gall midges, the difficulty of rearing them and their marked fragility have resulted in more attention being paid to the galls than to the insects. The producer in most cases is more interesting than the product and we wish for just a moment to call attention to some of the more striking features of the 900 species belonging to over 70 genera.

The antennæ are unusually interesting structures, the normal number of segments is probably 16, though a very large proportion of the gall midges have but 14 antennal segments.

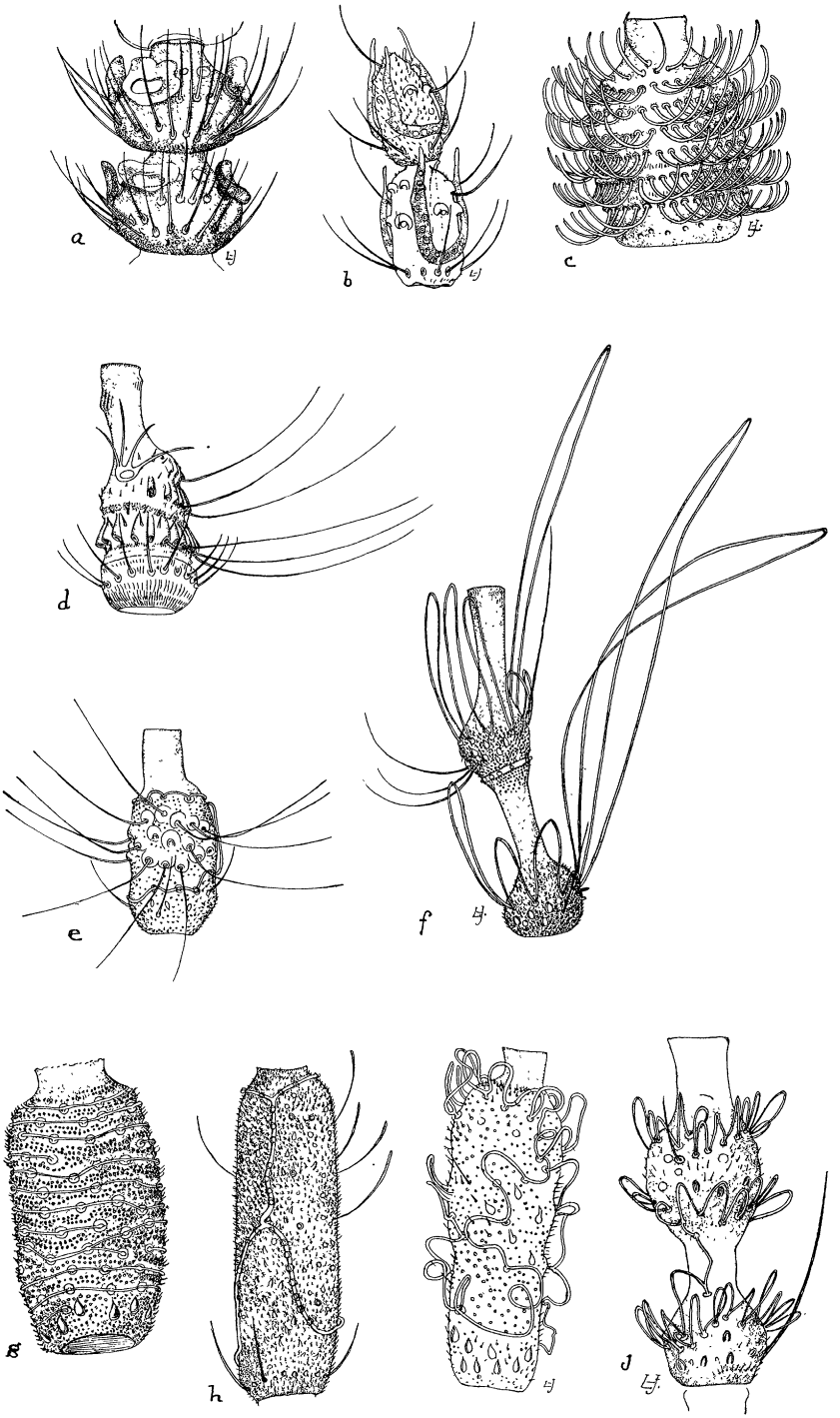
[16] *Phytophaga rigidæ* O. S.
[17] *Itonida inopis* O. S.
[18] *Cecidomyia ocellaris* O. S.

The extremes range from but eight in *Tritozyga* and *Microcerata* to thirty-three in *Lasioptera querciperda* Felt. These segments vary from relatively simple cylindric units with no particularly efficient sense organs to dumbbell-shaped structures with highly specialized "bow whorls," "arched filaments" or, as we prefer to call them, circumfili.

The more generalized midges are inhabitants of decaying organic matter and bear on their antennæ a variety of olfactory organs. The most interesting of these are the stemmed discs of *Monardia,* though in the same tribe we have the subapical flaring collars and in certain Lestremiinæ striking digitate processes; crenulate whorls are peculiar to the Campylomyzariæ, a simple type being seen in *Corinthomyia,* while the more common and probably the more highly specialized form is to be seen in *Prionellus.*

The "bow whorls," "arched filaments," or circumfili are exceedingly peculiar. In the first place, these homogenous structures have markedly different optical properties from the usual sensory hairs or setæ and are invariably connected in series of low or high loops, the union between the component elements being so perfect that there is no sign of division, no perceptible enlargement and no indication of weakness. They reach their maximum development in the male Diplosid and are characteristic of the most specialized subfamily (Itonididinæ) of the gall midges. The primary type is a low subbasal and subapical circumfilum united on one face of the segment by a nearly longitudinal filum. One of the most peculiar is the horseshoe-like modification, nails and all being simulated, on opposite faces of the antennal segments in *Winnertzia* of the Epidosariæ, a tribe with a marked tendency to hyperdevelopment of these structures. The males of *Asphondylia, Schizomyia* and *Cincticornia* also show peculiar modifications.

Males of the most specialized tribe (Itonididinariæ) exhibit the extreme development of these sturctures. They may have two or three whorls of long loops, the former we have designated as the bifili, the latter as the trifili, believing this subtribal division worthy of recognition. In each of these subtribes we may find among the males genera with relatively low loops as in *Thecodiplosis* and *Hormomyia* and many with extremely long loops, such as *Contarinia* and *Bremia,* the latter remarkable because of the great prolongation of two loops and especially on account of the thread-like middle circumfilum characteristic of the female.



THE ANTENNÆ, OR FEELERS OF INSECTS, are highly developed sense organs and the

We may also note that the palpi of the gall midges vary from well-developed four-segmented organs, nearly as efficient as the greatly reduced antennæ of some genera, to minute rudimentary lobes, and in one or more species these organs seem to have disappeared. This tendency toward reduction has arisen independently in several widely separated genera.

There is likewise great modification in the number of tarsal segments, they ranging from one to five; the entire subfamily Itonididinæ having the first tarsal segment greatly reduced. There are certain American genera where there is a reduction in tarsal segments from five to four, to three and in one to two tarsal segments.

The wings, organs which might be expected to respond to environmental agencies slowly, show variations from a structure with five or six veins to one with but one or two veins and in a few extreme cases there are none. The female of one European species has lost the organs of flight.

The association of characters in gall midges is so marked that the presence of one structure means the existence of others and indicates a probable similarity of habits. The *Campylomyza* wing postulates, the long first tarsal segment and larvæ feeding for the most part in dead organic matter, the well-developed crossvein, the short first tarsal segment and the tendency toward the bizarre in the circumfili indicate the Epidosariæ, a group confining itself largely to dead organic matter. The generalized wing of *Rhabdophaga* with the comparatively simple antennæ, quadriarticulate palpi and toothed claws defines a dominant willow group, while the similar *Rhopalomyia* with its reduced palpi and simple claws insistently murmurs solidago buds. *Asphondylia* with its peculiar antennæ, reduced palpi and aciculate ovipositor is satisfied with practically nothing except buds, while the related *Cincticornia* with its

above illustrations give some idea of the wonderful variety of structure to be found in the gall midges. Gall-midge antennæ may be composed of from eight or nine to thirty-four jointed elements or segments. The simple cylindrical segment is indicated in Figs. *G*, *H* and *I*. The same with a stem-like projection is shown at *D* and *E*, while the greatly modified dumbbell type is seen at *F* and *J*. These organs bear peculiar sensory structures, such as stemmed disks, shown at *A* and finger-like or digitate processes near the tip at *D*. There may be few or numerous short or long hairs and in the case of *C* these hairs may be modified into series of stout curved growths running around the segment. Among the most peculiar structures found on the antennæ are the "arched filaments" or "bow whorls" or circumfili. These may be low and few in number as at *E* and *H*, numerous as in *G*, somewhat higher as in *I*, still longer as in *J*, or enormously produced as shown in *F*. One of the most peculiar modifications of the bow whorls is the horseshoe-like structures, nails and all, represented on the two segments illustrated at *B*. These bow whorls under a microscope are very different from the ordinary hairs. The illustrations are all made at approximately the same enlargement and with the exception of *A* and *B*, each figure represents one segment.

quadriarticulate palpi must have oak leaves in the bud and the peculiar *Caryomyia* insists upon hickory.

There are three important groups of gall-makers, the gall midges responsible for 679 deformities, the gall wasps remarkable for their high specialization and the peculiar and extremely interesting alternation of generations inhabit some 445 galls, while plant mites have been listed from 161 galls. The host preferences of these numerous forms are very marked, as evidenced by the following tabulation:

PRINCIPAL HOST PREFERENCES OF AMERICAN GALL INSECTS

Hosts	Gall Midges	Gall Wasps	Gall Mites
Pines and cedars	35		
Grasses	33		
Willows	66		23
Oaks and chestnut	43	353	17
Rose family	56	38	27
Legume family	24		
Maples	13		34
Grape and Virginia creeper	22		7
Composites	150	12	3
Total for all plants	679	445	161

It is obvious from the above that a close correlation must exist between plants and gall-making insects which live upon them. Generally speaking, groups of plants presenting numerous widely disseminated, closely related forms are acceptable hosts to many gall insects and frequently the members of one order, of a tribe, or even a genus may be closely limited to such plants and in some instances to species or closely related species. For example, gall wasps attacking red oak and its allies are not found on the white-oak series, and vice versa. This great diversity in structure and habits of gall insects is evidently a response to environment and is made necessary by the physical unfitness of adults or larvæ to withstand other conditions. These insects are small in size, fragile, local in habit, mostly slow of flight and generally far from being unusually prolific. Nevertheless, hundreds of species are able to maintain themselves, frequently in large numbers, in spite of apparently unfavorable conditions.

It must not be concluded from the above, lengthy though this may be, that there is nothing yet to learn about gall insects and the deformities they inhabit. New species and new genera are awaiting discovery, the biology of many gall insects and especially of gall wasps is still unraveled. The great variety

of galls upon the oaks, many of them attractive in color, delicate in texture and comparatively unknown, challenge our admiration and incite to further study. The same is true of the many and varied deformities inhabited by the fragile gall midges, species which have learned to subsist upon various parts of a large variety of plants. The gall mites, microscopic though they are, invite the attention of the student.

Insect galls are to be found in all parts of the country and they and their makers present a charming and delightful field of study which may be entered with profit by the child at school as well as by the student of more mature years.

The poet must have dreamed of some such condition when he wrote:

> And Nature, the old nurse, took
> The child upon her knee,
> Saying, "Here is a story book
> Thy Father has written for thee."
>
> "Come, wander with me," she said,
> "Into regions yet untrod;
> And read what is still unread
> In the manuscripts of God."—LONGFELLOW.